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NICKEL/CADMIUM AIRCRAFT BATTERIES: RAPID ELECTROLYTE EXCHANGE T--ETC(U)
APR 77 K FELDMAN; R M HAYASHI
DREO-TN-77-8

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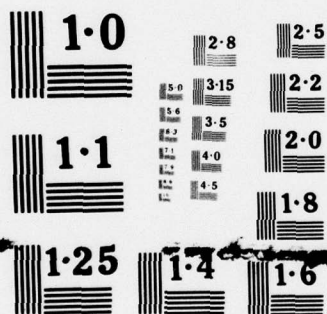
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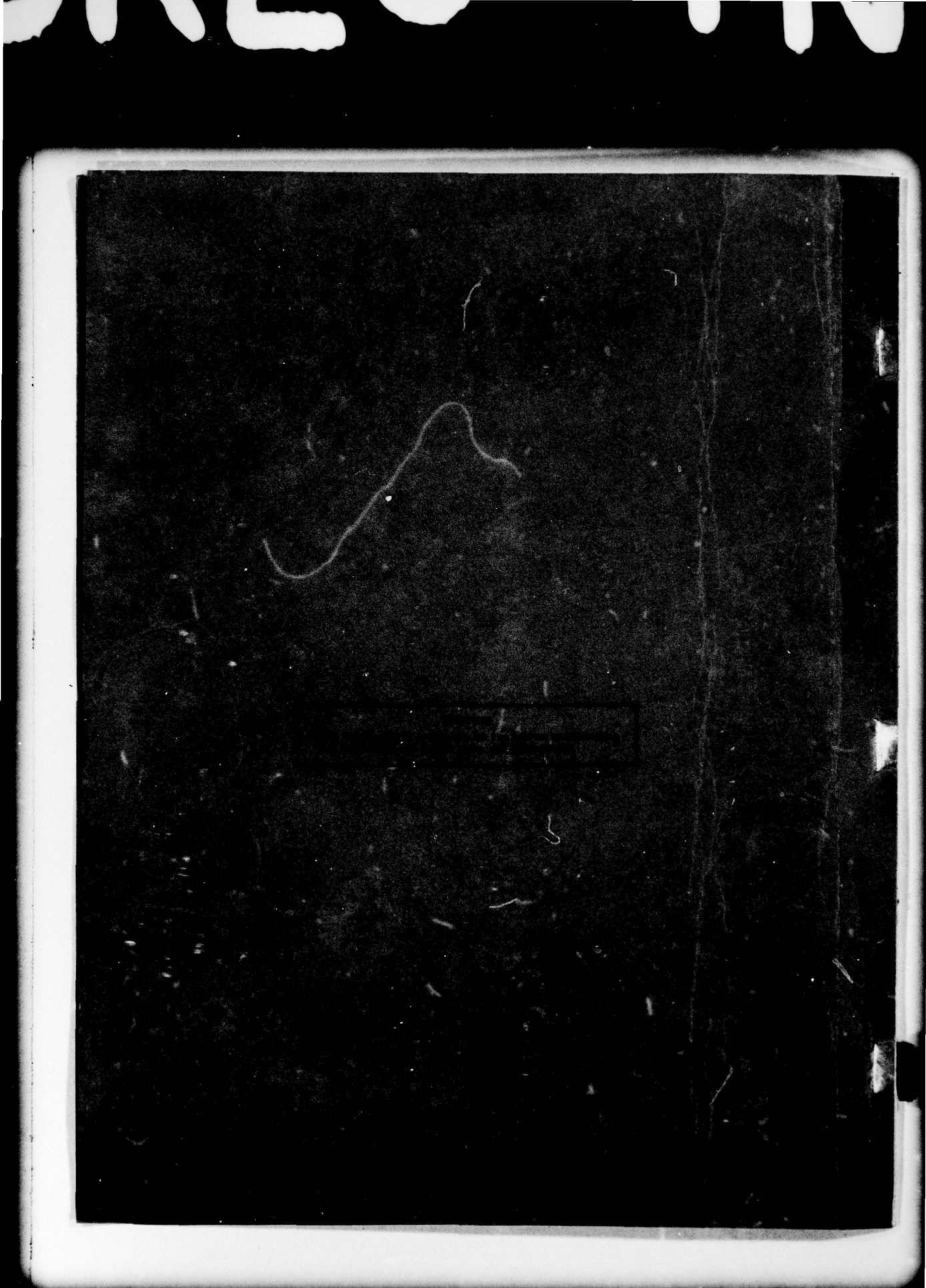


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RESEARCH AND DEVELOPMENT BRANCH

DEPARTMENT OF NATIONAL DEFENCE
CANADA

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

(9) TECHNICAL NOTE NO. 77-8

(14) DREO-TN-77-8

(6) NICKEL/CADMIUM AIRCRAFT BATTERIES:
RAPID ELECTROLYTE EXCHANGE TECHNIQUE

by

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Electrical Power Sources Division

404 576
D D C
RECEIVED
MAY 12 1977
A

~~PROJECT NO.
54-0307~~

* On contract from Computing Devices Company

77-087

RECEIVED APRIL 1977
PUBLISHED APRIL 1977
OTTAWA

(11) (12) 150.
DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

688

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ABSTRACT



The potassium hydroxide electrolyte in nickel/cadmium aircraft batteries may become increasingly more contaminated by carbonate with battery use. When the carbonate concentration exceeds certain limits it is advisable to exchange the electrolyte. However, most of the electrolyte in a cell is soaked into the separator materials and plate pores, and is held in the pack, so only a small portion of it may be poured out. Repeated removal and replacement of these small amounts can accomplish the desired exchange if the clean added electrolyte is adequately mixed with the contaminated electrolyte each time. In the normal procedures, mixing is accomplished by discharging and recharging the battery after each small exchange and hence is very time consuming.

This paper discusses the various factors involved and presents a vacuum technique for mixing the added with the retained electrolyte in each cell. The method presented reduces the time required for the above operation from a week or more to a day or two.



RESUME

L'électrolyte d'hydroxyde de potassium dans les batteries nickel/cadmium des aéronefs peut devenir contaminé par le carbonate. Au-delà de certaines concentrations de carbonate, il est préférable de changer l'électrolyte. Cependant, la majeure partie de l'électrolyte est absorbée dans le séparateur et dans les pores des plaques; on ne peut donc qu'en enlever une petite partie à la fois. En répétant l'opération, on peut obtenir le résultat voulu si, chaque fois, l'électrolyte propre ajouté est bien mélangé à l'électrolyte contaminé. Normalement, on y parvient en déchargeant et en rechargeant la batterie à plusieurs reprises, ce qui prend énormément de temps.

Le présent document examine les divers facteurs en cause et offre une méthode de mélange des deux électrolytes dans chaque cellule par le vide. On peut ainsi réduire le temps nécessaire pour diminuer la concentration de carbonate, d'une semaine ou plus à un jour ou deux.

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INTRODUCTION

The electrolyte in nickel/cadmium aircraft batteries is a solution of potassium hydroxide in water. Canadian Forces specifications limit the concentration of the potassium hydroxide to $31.5\% \pm 1.5\%$ and restrict carbonate contamination to a maximum of 5%, by weight (1). If the potassium hydroxide concentration is found to be outside the specified range (say, due to "topping-up" with water after repeated losses by spillage, or with concentrated potassium hydroxide solution after losses due only to electrolysis), it can be corrected by removing some of the electrolyte and replacing this with concentrated solution, or with water, as the case requires. However, if the electrolyte becomes sufficiently contaminated with carbonate, it is necessary to exchange it, i.e. to replace most of the old electrolyte with new electrolyte.

The problems associated with this exchange are discussed in this paper and a method of carrying out the procedure in a day or two is presented. Conventional methods may require a week or two and in some cases even more.

ELECTROLYTE DISTRIBUTION IN THE CELL

The plates and the separator materials in sintered plate, flooded nickel/cadmium cells are highly porous. Much of the electrolyte in the cell is therefore soaked into the pores and clings to the surfaces of these components. Furthermore, the baffle located below the vent cap frequently makes it difficult or impossible to remove all of the electrolyte which is free in the cell. The extent of these limitations may be illustrated by this example. A 22 ampere-hour cell constructed of dry materials required 130 ml of electrolyte to fill it to the proper level. Later attempts to empty the cell yielded only 32 ml. Thus three-quarters of the electrolyte remained in the cell.

Because of the above facts, if the carbonate content in a cell becomes excessive, it is necessary to reduce it by repeatedly draining the small amount of electrolyte which can be removed and admixing fresh solution with what remains in the cell. In the above cell, for example, if the carbonate

content was 12% and 32 ml of solution were removed and replaced by pure potassium hydroxide solution (and neglecting the resulting change in density as well as the small amount of carbonate likely to be present in fresh solution added), the exchange would bring the level down to $.12 (130-32)/130 = 9\%$. A second exchange would bring it to $.09 (130-32)/130 = 6.8\%$. Third and fourth exchanges would give 5.1% and 3.9% respectively. The latter is within the tolerance normally required to be achieved.

In laboratory practice it has been found that, with the level of contamination in the above example, five or six exchanges are usually required to achieve the desired result.

IMPLICATIONS OF EXCHANGE TECHNIQUE

The above example assumed that prior to each succeeding exchange, the old and the added electrolyte were uniformly mixed. If this is not so, the number of required exchanges is increased. In the limiting case of no mixing, the next exchange would remove only the fresh solution and no improvement would be achieved.

The second assumption in the example, that the maximum amount of free electrolyte was removed from the cell each time, is rarely achieved in practice. Unless a good technique is used, it is quite possible that only about one half as much, or less, is actually removed. This can readily double the number of time-consuming exchanges required.

It is obvious from the above that the expeditious upgrading of the electrolyte in these batteries demands effective techniques for thorough mixing and for maximum removal of solution each time. These are discussed separately below.

ELECTROLYTE REMOVAL TECHNIQUE

As discussed above, the two major difficulties in removing electrolyte from the cell are due to obstruction by the baffle and to retention of the solution in the plate pack. However, when a cell is being charged and is gassing vigorously, gas bubbles generated at the plates tend to expel some of the electrolyte from the pores. When charging is terminated, many of the gas

bubbles escape from the pores and the electrolyte once more recedes into them. Advantage may be taken of these facts by having everything in readiness (such as vent caps removed) so that the cell or battery may be inverted to drain the electrolyte within seconds of the termination of charge. In this way the maximum amount of electrolyte may be removed from the plate pack.

The measure of success which may be attained in removing from the cell the electrolyte which the above procedure frees from the plate pack depends on the baffle details. However, in all cases observed, the maximum was removed when the battery was completely inverted and rocked slowly from side to side and backward and forward. (It is not satisfactory to lay the battery on its side and attempt to remove the electrolyte by use of a syringe or other similar method).

The above procedure, when a whole battery is to be emptied, may be greatly facilitated by the use of a suitable jig so that the weight of the battery need not be supported by the operator. Aside from the question of easing the physical exertion otherwise needed, the jig permits the operator to observe the flow of electrolyte from the battery so the rocking motion may be continued until the flow ceases. See Appendix I.

MIXING TECHNIQUE

The conventional procedure for mixing the added with the retained electrolyte is to completely discharge and recharge the battery. During the discharge much of the electrolyte is drawn into the plate pack and is expelled again during the recharge. However, this procedure normally requires several hours. It has been found that a somewhat similar mixing action may be achieved rapidly as follows.

The battery is charged until all of the cells are gassing vigorously. While charging, a vacuum is applied for a few seconds to each cell (see Appendix II). This causes the gas bubbles throughout the cell to expand and more rapidly rise to the surface. The vacuum is then suddenly removed. The abrupt increase in pressure in the cell collapses any low pressure bubbles then in the plate pack and the free electrolyte rushes in to fill the voids. As charging continues, more gas is generated and the original condition is reached once more. This process tends to simulate the mixing that occurs when the battery is discharged. Hence after a few applications of vacuum to each cell, the electrolyte may be exchanged and the process repeated again. Thus several exchanges may be carried out in an hour or two.

Precautions should be taken to avoid damage to vacuum equipment by entrained droplets of the caustic electrolyte. If a regular vacuum line or

suitable vacuum pump are not available, an aspirator attached to an ordinary water tap is adequate. (See for example, Fisher aspirator pumps, catalogue no. 9-956, 9-960-2, etc.).

The effectiveness of the above procedures may be monitored by doing the normal titration analysis on a few cells at various steps in the process. Electrolyte exchanges may be repeated as many times as considered expeditious. Also, since carbonate concentrations may under some conditions, collect in the plate materials (as distinct from being located in electrolyte in pores), it may be necessary to include one or two charge-discharge cycles as well. However, these can be planned to coincide with the normal battery shop reconditioning cycles.

Most of the laboratory experience in the use of this vacuum technique for mixing has been gained on cells using Celgard in the separators. Since this material is comparatively strong, there was no question of possible damage resulting from the vigorous flow of electrolyte through the plate pack. Cellophane in separators is probably much more vulnerable, especially if it is already deteriorated. A very limited test was made on a battery containing badly deteriorated cellophane. In this test the electrolyte was exchanged numerous times, with the vacuum method being used on one-half of the cells and the conventional method on the others. No significant difference was found between the failure rates of the two sets of cells. However, the test was too limited to be considered as conclusive evidence that the method may be used on cellophane containing cells without danger of damage.

SUMMARY

The use of proper techniques minimizes the number of electrolyte changes required to bring excessive carbonate concentrations down to the required level. The use of the vacuum technique described provides suitable mixing of electrolyte retained in the plate pack with the added fresh electrolyte, between exchanges, without time consuming charge-discharge cycles. A suitable jig for use in emptying electrolyte can promote maximum removal of electrolyte each time to minimize the number of exchanges required.

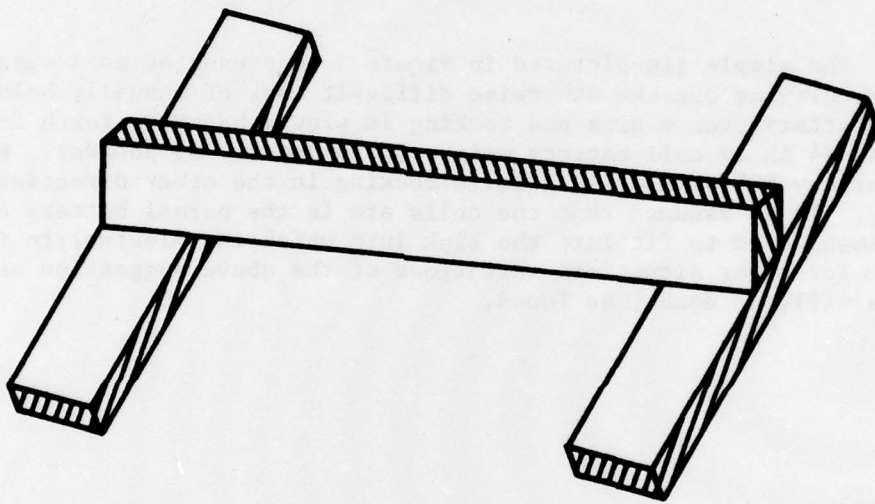
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APPENDIX I

JIG FOR USE IN EMPTYING ELECTROLYTE FROM AN AIRCRAFT BATTERY

The simple jig pictured in Figure 1 is presented as a suggestion for an aid in carrying out the otherwise difficult task of manually holding an inverted battery over a sink and rocking it slowly back and forth for several minutes (a 34 Ah 19 cell battery weighs approximately 85 pounds). Rotating the battery by 90° on the jig permits rocking in the other direction when necessary. It is assumed that the cells are in the normal battery case. The jig is dimensioned to fit into the sink into which the electrolyte is to be emptied. For other situations variations of the above suggestion or other solutions will, no doubt, be found.



*Fig. 1: Jig for Battery Support While
Draining Electrolyte*

Material: Wood 2" X 4"

APPENDIX II

VACUUM APPLICATION TO CELLS

The application of vacuum to the individual cells may conveniently be carried out with a modified vent cap attached to a vacuum line. The vent cap is modified by removing the venting attachment and drilling the hole to accept a short length (say 3 inches) of lucite tube. This is epoxied into place. The vacuum line is attached to the lucite tube by means of rubber or plastic tubing.

In use, the cap is put into place and held firmly against the seat (but is not turned to engage the thread). After 5 to 10 seconds the vacuum is released by lifting the cap off.

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Security Classification

DOCUMENT CONTROL DATA - R & D		
(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)		
1. ORIGINATING ACTIVITY Defence Research Establishment Ottawa National Defence Headquarters Ottawa, Ontario, Canada K1A 0Z4		2a. DOCUMENT SECURITY CLASSIFICATION Unclassified
		2b. GROUP N/A
3. DOCUMENT TITLE Nickel/Cadmium Aircraft Batteries: Rapid Electrolyte Exchange Technique (U)		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Technical Note		
5. AUTHOR(S) (Last name, first name, middle initial) K. Feldman and R.M. Hayashi		
6. DOCUMENT DATE February 1977	7a. TOTAL NO. OF PAGES 9	7b. NO. OF REFS 1
8a. PROJECT OR GRANT NO. 54-03-07	9a. ORIGINATOR'S DOCUMENT NUMBER(S) DREO Technical Note No. 77-8	
8b. CONTRACT NO.	9b. OTHER DOCUMENT NO.(S) (Any other numbers that may be assigned this document)	
10. DISTRIBUTION STATEMENT UNLIMITED DISTRIBUTION		
11. SUPPLEMENTARY NOTES	12. SPONSORING ACTIVITY DAASE	
13. ABSTRACT <p>The potassium hydroxide electrolyte in nickel/cadmium aircraft batteries may become increasingly more contaminated by carbonate with battery use. When the carbonate concentration exceeds certain limits it is advisable to exchange the electrolyte. However, most of the electrolyte in a cell is soaked into the separator materials and plate pores, and is held in the pack, so only a small portion of it may be poured out. Repeated removal and replacement of these small amounts can accomplish the desired exchange if the clean added electrolyte is adequately mixed with the contaminated electrolyte each time. In the normal procedures, mixing is accomplished by discharging and recharging the battery after each small exchange and hence is very time consuming.</p> <p>This paper discusses the various factors involved and presents a vacuum technique for mixing the added with the retained electrolyte in each cell. The method presented reduces the time required for the above operation from a week or more to a day or two.</p> <p style="text-align: center;">UNCLASSIFIED</p>		

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KEY WORDS

**Nickel/Cadmium Aircraft Batteries
Rapid Electrolyte exchange
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